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The Edinburgh cognitive and behavioral amyotrophic lateral sclerosis screen (ECAS)

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The Edinburgh Cognitive and Behavioural Amyotrophic Lateral Sclerosis Screen (ECAS): Sensitivity in Differentiating between ALS and Alzheimer's Disease in a Greek Population.

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The Edinburgh Cognitive and Behavioural Amyotrophic Lateral Sclerosis Screen (ECAS): Sensitivity in Differentiating between ALS and Alzheimer's Disease in a Greek Population.

Objectives: 1) Adapt the ECAS into Greek, validate it in ALS patients and compare with the ALS-CBS 2) Determine the sensitivity and specificity of ECAS in the differentiation between AD and non-demented ALS patients as compared with the ACE-III and mini-ACE.

Methods: ALS patients (n=28) were recruited. and AD patients (n=26) matched in age, sex, and education with ALS patients (n=24). The normative data was derived from a random sample of controls (n=52). Bayes correlation analysis was conducted to examine convergent validity. Bayes t-test was performed to assess between groups' differences. Receiver operating characteristics (ROC) curve analyses and area under the curve (AUC) were implemented to appraise the sensitivity and specificity in the differentiation between AD and non-demented ALS patients.

Results: The ECAS and its sub-scores in addition to the behaviour interview demonstrated robust correlations with the ALS-CBS. Impairment in language and verbal fluency were the most prominent deficits in the ALS patients. The most frequently reported change was apathy. The ROC analysis demonstrated that the ECAS-ALS Non-Specific score (comprising memory and visuospatial domains) is the most sensitive and specific in differentiating AD from ALS patients. The other measures expressed high sensitivity, yet a poor specificity.

Conclusions: The ECAS is a multi-purpose screening tool. The ECAS-ALS Specific appraises the whole spectrum of the highly prevalent cognitive impairments in ALS. The ECAS-ALS Non-Specific (memory and visuospatial) is a sensitive score to detect AD related deficits and is able to differentiate AD from non-demented ALS patients better than the ACE-III and mini-ACE

Keywords: Greek; ECAS; ALS; Alzheimer's Disease; ACE-III

Introduction

Cognitive impairment in the ALS can be found in 15–60% of patients [1, 2], whilst almost 10% present with frontotemporal dementia (FTD), with the behavioural variant (bvFTD) being most prevalent [1, 3]. The most ubiquitous deficits in ALS are related to executive dysfunction and verbal fluency [4]. However, evidence of language deficit and compromised social cognition have been revealed [5–8]. Behavioural changes include apathy and disinhibition, similar to those in bvFTD [8]. Accordingly, diagnostic criteria have been proposed to differentiate between ALS with cognitive (ALSci) and/or behavioural changes (ALSbi) and ALS with FTD incorporating the recent findings of a more heterogeneous cognitive profile [9].

The ALS Cognitive Behavioural Screen (ALS-CBS) is the sole screening tool detecting cognitive impairment in ALS that has been translated into Greek [10]. It is a short bedside screen (administration time ≤ 10 mins) that assesses frontal lobe-mediated cognitive and behavioural changes [10, 11]. Studies in ALS have demonstrated that 40–50% of patients show impairment on conventional tests of executive functions [2, 5, 12]. The ALS-CBS includes a section that assesses executive functions and appears to be an appropriate tool to assess ALS patients [10, 11]. However, it has not been designed to assess the more recently recognized heterogeneous cognitive impairments in ALS, namely in language and social cognition [9].

Alternatively, the Edinburgh Cognitive and Behavioural ALS Screen (ECAS) has been developed as a more comprehensive brief assessment [13, 14]. It has been adapted for Italian [15], German [16], Chinese [17], Dutch [18], and Spanish [19] populations. The ECAS is a brief screening tool (administration time approximately 20 mins) that is adjustable for patients with various motor impairments. It comprises a comprehensive assessment of a spectrum of cognitive and behavioural abnormalities in ALS [9, 13–19]. Furthermore, it has been validated in detecting the milder focal impairments in ALS (14, 20). The ECAS comprises an ALS-specific score (executive function, social cognition, verbal fluency, and language), an ALS-non-specific score (memory and visuospatial functions), and a carer's interview to detect the behavioural and psychotic changes typical in FTD [9, 13–19]. Importantly, the ECAS assesses the recently recognized impairments in inhibitory control [10], social cognition [21], and language, which have been reported as highly prevalent in ALS [6, 7]. In particular, it assesses object naming [22, 23], utility and comprehension of

verbs [24], and spelling [25]. Furthermore, the ECAS has been designed to identify the changes that are not typical of ALS but are characteristic of other disorders, particularly Alzheimer's disease (AD) [13]. However, the profile of impairment on the ECAS in AD is yet to be demonstrated.

This study aimed to 1) Adapt the ECAS into Greek, validate it in ALS patients and compare it with the ALS-CBS. It should be noted that the ECAS has demonstrated good convergent validity with the ALS-CBS in a Spanish ALS population [19]. 2) Determine the sensitivity and specificity of ECAS in the differentiation of AD from non-demented ALS patients as compared to the ACE-III and mini-ACE. The relationship between the ACE-III and the ECAS has been previously examined in a healthy population, and the ECAS was found to be less affected by IQ and ceiling effects [26].

Methods and Materials

Participants

All the participants and/or their carers signed an informed consent form in compliance with the revised Declaration of Helsinki, 1987. The present study was approved by the Psychology Research Ethics Committee of the University of Edinburgh and the Aeginition Hospital Ethics Committee. All participants had to be Greek native speakers and be free from the following: (1) psychiatric disorders, (2) psychoactive drugs, antidepressants, and anticonvulsants, (3) neurological conditions affecting cognition (other than ALS and AD for the respective patients), (4) learning disabilities, (5) alcoholism and drug abuse, and (6) uncontrolled systemic disease.

ALS Patients

The ALS patients (n = 28) were recruited in the Neurological Clinic (inpatients) and ALS Clinic (outpatients) of Aeginition Hospital, Athens, Greece. The recruitment was conducted in accordance with the general inclusion criteria and the following inclusion criteria specific to ALS: (1) a diagnosis of definite, probable, probable and laboratory-supported, or possible ALS based on the revised El Escorial criteria [27], (2) no clinical diagnosis of frontotemporal dementia as defined by the Neary et al. criteria (FTD) [28], and (3) absence of significant respiratory failure (forced vital capacity < 70%). A neuropsychologist and/or psychiatrist interviewed the patients and administered the ALS Depression Inventory (ADI-12) (cut-off > or = 23) [30] to discount patients with major depressive symptomatology. The patients' motor

ability was evaluated using the revised Amyotrophic Lateral Sclerosis Functional Rating Scale (ALSFRS-R) [29]. The disease duration was calculated in months, from the onset of first symptoms to the testing date. Lastly, 28 caregivers (close relatives of the patients) of the ALS were interviewed to assess behavioural changes in ALS.

AD Patients

AD patients (n = 26) of the Maroussi Alzheimer Clinic, Athens, Greece were recruited to match a subgroup of ALS patients (n = 24) in age, sex, and education. The recruitment was conducted in accordance with the general inclusion criteria and the following inclusion criteria specific to AD: (1) a diagnosis of AD according to the National Institute of Neurological and Communicative Disorders and Stroke/Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA) [31], (2) an absence of a mixed concomitant dementia processes (e.g., AD and vascular dementia). A neuropsychologist and/or psychiatrist interviewed the patients and administered the Hospital Anxiety and Depression Screen (HADS) [32] (cut-off > or = 8) to discount the patients who presented major depression or anxiety symptoms that may compromise their performance. The duration of the disease was calculated in years, from the onset of the first symptoms to the testing date. Lastly, 26 caregivers (close relatives of the patients) of the AD patients were interviewed to assess behavioural changes in AD.

Healthy Subjects

108 healthy participants were recruited who were either (1) members of Athens Association of Alzheimer's Disease and Related Disorders, Athens, Greece; (2) or members of the ALS HELLAS patients' association; (3) or volunteers who responded to the calls of the aforementioned associations. For the recruitment we implemented the above-mentioned general inclusion criteria. 56 were recruited to provide the data for the verbal fluency index (VFI) conversion tables of ECAS. A separate group of 52 healthy participants were recruited to form the ECAS normative data. These groups were distinct from each other with no overlap.

Procedures

Translation-Adaptation

The adaptation of ECAS was conducted in accordance with the guidelines by Abrahams et al.,2014 (https://ecas.psy.ed.ac.uk/)[13]. The ECAS comprises a written or spoken verbal fluency task of the letters 'S' and 'T'. The letters 'Σ' (Sigma) and 'Π' (Pi) were opted for the Greek version. The letter 'Σ' in Greek resembles the difficulty of 'S' in English [33], while 'Π'

is similar to the difficulty level of 'T' in English. However, the rule of producing words using only 4 letters was modified to 5 letters due to the scarcity of 4-letter words in Greek. The spoken and written versions of both letters were administered separately to a different sample of healthy controls to produce the VFI conversion tables of ECAS (see Box 1 in Supplementary Material). The calculations were made as per the ECAS translation instructions [13].

The adaptation of ACE-III and M-ACE in Greek required minor modifications, since most of the tasks remained the same as in ACE-R. The sole significant adjustment was in the task of proverb repetition. In terms of pronunciation, the first item should be a low-difficulty proverb, i.e., 'All that glitters is not gold' and the second item should be a medium- to hard-difficulty, i.e., 'A stitch in time saves nine'. The proverbs of the Greek version are culturally adjusted and correspondent to this difficulty measure, i.e., 'All that glitters is not gold' and 'Better donkey-tying than donkey-seeking'.

Administration of Screens - Spoken and Verbal Versions of ECAS

The 52 healthy participants for the normative data were allotted to two groups matched in age, sex, and education. The spoken version of the ECAS was administered to the first group, while the written version of the ECAS was administered to the second. The rest of the screens were administered to both groups.

Statistical Analyses

Thresholds of $p < 0.05$ (two-tailed) and $BF_{10} \geq 10$ were used for statistical inference. The demographic and cognitive data were analysed and compared. Between-group comparisons were made via Bayesian independent sample t-tests. Bayesian Pearson Correlation Analysis was used to assess the associations between screening tools. Receiver operating characteristics (ROC) curve analyses and area under the curve (AUC) were implemented to appraise sensitivity and specificity in the differentiation between AD and non-demented ALS patients. The statistical analyses were executed using the IBM Statistical Package for the Social Sciences (SPSS) 24.0. (Scale, ROC, and AUC analyses) [34], and JASP version 0.8.1.2 (Bayesian Pearson's Correlation analyses, Bayesian t-tests) [35].

Inter-Rater Reliability & Internal Consistency

The inter-rater reliability between the assessors and the independent interviewer was appraised using the Intraclass Correlation Coefficient (ICC), which displays the outcomes from 'no match' = 0 to 'seamless match' = 1 [36] (see Box 2 in Supplementary Material). The internal

consistency of the Greek versions of ECAS and ACE-III was determined by the calculation of Cronbach's alpha coefficient. A Cronbach's alpha coefficient of 0.70 or greater was considered substantial [37].

Results

The descriptive statistics of the normative sample are displayed in Supplementary Material Table 1, together with the suggested cut-offs for abnormality. No significant difference was detected between the written and spoken versions of the ECAS.

Inter-Rater Reliability & Internal Consistency

The inter-rater reliability analysis displayed ICC = 0.88 for the ECAS, which postulates an almost seamless agreement between the assessors and substantial suitability for clinical implementation [36]. The scale analyses demonstrated an excellent internal consistency with Cronbach's alpha = 0.84 [37].

Correlations with Education & Age

Educational level correlated with the total score of ECAS but not with the ECAS-ALS Specific, ECAS-ALS Non-Specific, ACE-III, M-ACE, and ALS-CBS (see Table 2 in Supplementary Material). Further, the age of participants did not correlate with any of the above scores.

Convergent Validity of ECAS against ALS-CBS

The ECAS and its sub-scores demonstrated a robust correlation with the ALS-CBS (see Table 3 in Supplementary Material). The ECAS Behavioural score also correlated with the ALS-CBS behavioural score. The subsequent Bayesian analysis of the correlations confirmed the convergent validity of the screens.

Cognitive and Behavioural Changes in ALS as Assessed by the ECAS

Impairment in language and verbal fluency were the most prominent deficits in ALS patients, followed by executive functions (see Figure 1). 64% of the ALS group presented with a behavioural change. The most frequent behavioural change was apathy, followed by loss of sympathy and perseverative behaviour (see Figure 2). Changes in eating behaviour were less commonly found among this population.

Differentiation between ALS and AD Patients

The researchers examined which screen or sub-score would be most effective in discriminating between AD and ALS patients. The ROC analysis demonstrated the ECAS-ALS Non-Specific score to be the most sensitive and specific in differentiating AD between ALS patients (see Figure 3). The other measures expressed high sensitivity but poor specificity. The sensitivity and specificity of each screen are displayed in Table 1. The ALS group performed significantly better than the AD group in all the measures (see Table 2). However, the former showed greater behavioural changes than the latter.

In ALS patients, the Bayes correlation pairs analysis revealed an absence of substantial evidence ($BF_{10} \geq 3$) for a correlation between either the total scores or the sub-scores of the tests and either the disease duration or ALSFRSR. The ECAS Behavioural and ALSFRS-R alone correlated significantly as r (26) = -44, p<.05, BF_{10} = 3.15.

Discussion

The ECAS in Greek Population

The present study validates the Greek ECAS in ALS patients and demonstrates good convergent validity with the already adapted Greek version of ALS-CBS for both cognitive and behavioural components. The ECAS also exhibited substantial internal consistency, allowing implementation in clinical and research settings [36], and excellent inter-rater reliability, permitting its extensive utilisation by various clinical practitioners [37]. Therefore, the Greek ECAS can be considered a valid and effective tool for clinical and research purposes.

Behavioural and Cognitive Changes in ALS

In the present study, 50% of the subjects were impaired on the ECAS Total score and 46% on the ECAS-ALS Specific score, which is in accordance with other studies [5, 12, 14–16]. The most prominent cognitive impairments were found in language (36%), verbal fluency (36%), and executive functions (32%), which aligns with the previous studies in ALS patients [5, 13–20, 38]. Moreover, the comorbidity of impairments was detected only in a small percentage of the ALS patients in language and verbal fluency (14%), language and executive functions (14%), verbal fluency and executive functions (14%), and language, executive function, and verbal fluency (11%).

The prevalence of executive function and verbal fluency in addition to language impairment in the current study is in accordance with the English, Italian, and German validation studies of ECAS [12, 13, 15] and with an extended systematic review of 44 neuropsychological studies with 1130 ALS patients, where language dysfunction appeared to be the most prevalent cognitive impairment [38]. These findings are aligned with the recently revised diagnostic criteria of Strong *et al.*, 2017 for cognitive and behavioural impairment in ALS [9].

The most frequently reported behavioural changes were apathy (54%), loss of sympathy (29%), and compulsive behaviour (22%). The first two changes have been considered as highly prevalent behaviour changes in previous studies [12–20]. The present study and the Italian validation study of the ECAS highlighted comparably high percentages of apathetic behaviour (54% and 45%, respectively) [15]. Moreover, an increased ECAS–Behavioural score was associated with poorer physical function, as assessed by the ALSFRS-R. These findings are, hence, in line with Lillo *et al.* (2012) and Crockford *et al.* (2018). It can be postulated that the behavioural changes seem to become prevalent in ALS as the neurodegeneration progresses and the functionality rate deteriorates [12, 39]. Notably, in this sample, neither the depression index, nor the ECAS-Behavioural score were related to any cognitive measure.

Differentiation of ALS cognitive and behavioural profile from AD

ALS patients presented with more behavioural changes than AD patients. However, these results should be interpreted cautiously. Behavioural changes in AD are more likely to be presented in the later stages of the disease, when cognitive decline is marked [40]. Our sample included early-to-mid-stage AD patients who presented mild-to-moderate cognitive decline. Therefore, we recommend caution in using the ECAS Behavioural screen alone to differentiate between ALS and AD patients; it should be used in conjunction with the cognitive performance profile.

In contrast, ECAS-ALS Non-Specific was the most sensitive and specific score when differentiating between AD and non-demented ALS patients. ACE-III and M-ACE were sensitive, but not specific, in differentiating between the diseases. The superior performance of the ECAS ALS Non-Specific could be attributed to its adjustments to motor disability. However, ACE-III and M-ACE do not accommodate for physical decline. Hence, the ALS patients' deficits were most likely exaggerated by these tests. Furthermore, the ECAS ALS Non-Specific score assesses memory and visuospatial abilities that are recognized to be

impaired disproportionately in AD. The sensitivity of the ECAS ALS Non-Specific score also permits the identification of AD in ALS patients, which is of great clinical benefit.

Utility of the Screens

The ALS-CBS is adjusted to possible motor impairments and comprises a behavioural assessment. The ALS-CBS efficiently detects frontal-mediated cognitive impairments and behavioural changes and requires a short administration time. However, it does not use a VFI to convert the score in the verbal fluency task, and it does not include a language task even though language impairment is highly prevalent among ALS patients [5, 9, 13–16, 38].

In contrast, the ECAS with two distinct sub-scores and the behavioural interview have displayed the characteristics of an exceptional multi-purpose screening tool. The behavioural outcomes may accompany the cognitive profile of the patient and inform about the probable caregiver's burden. The ECAS-ALS Specific appraises the whole spectrum of highly prevalent cognitive impairments in ALS patients [9, 13–20]. The ECAS-ALS Non-Specific is a sensitive screening tool used to detect AD-related deficits and to differentiate AD patients from non-demented ALS patients. In poly-pathological clinical settings, where possible motor disabilities are prevalent amongst patients, the ECAS is an indispensable screening tool. However, in patients with severe motor dysfunction in upper limbs and impaired speech, tests that use brain machine interface [41] or eye-tracking technology [42] may be more appropriate [41, 42].

The study is limited by the small size of the sample. Also, in accordance with previous studies, the educational level was associated with both, the ECAS and the ACE-III [11, 15–17]. However, the ACE-III appeared to be significantly more dependent on the IQ and with greater ceiling effects than the ECAS, which may be an important advantage of the ECAS for use among clinical populations [26]. In the current study, cut-offs adjusted to the educational level are not specified. The healthy participants in this study belonged to an older age range (63% > 60) and had a low educational level (62% < 13 years). The abnormality cut-offs presented here are, therefore, conservative. The absence of adjusted cut-off scores may have influenced the estimates of abnormality rates. Furthermore, the validation of the ECAS was against ALS-CBS, which does not assess the whole spectrum of cognitive changes in ALS patients. Thus, in line with previous studies, validation against a comprehensive neuropsychological battery [14, 20] as well as the acquisition of larger normative data to calculate adjusted cut-offs to the educational level are strongly recommended [15, 18, 43, 44]. In this study, only ALS patients without dementia were recruited, and their genetic status was

unknown. Future studies can investigate the ALS-FTD profile and genetic subtypes. In conclusion, this study demonstrates a highly effective tool for evaluating the range of cognitive and behaviour changes in the Greek population that can assist in managing patient care and alleviating the caregivers' burden.

Declaration

The authors declare no conflicts of interest and that this study is their own work.

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Supplementary Material – ALS

<u>Box 1 – Verbal Fluency Index Calculation</u>

15 males and 13 females, age 57.07 years old (11.28), education 12.6 years (2.87), were tested in the spoken task of both letters (Π and Σ) to produce two discrete tables of the spoken Σ and Π. 28 healthy participants, 12 males and 16 females, age 56.97(9.15), education 13.73(2.84), were examined in the written task of both letters to develop the distinct tables of written Σ and Π.

<u>Box 2 – Inter-Rater Reliability</u>

The 4 assessors and the independent reviewer were equally trained in the administration and scoring of ECAS based on the relevant guidelines (https://ecas.psy.ed.ac.uk/). The 4 assessors administered the screens to healthy participants (N=52), ALS patients (N=28), and AD patients (N=26). The responses of the examinees were also recorded (typed) in a distinct sheet, which were solely accompanied with an id-number to maintain traceability and anonymity. The independent reviewer hence was blinded to the identity of both the examiner and the examinee. The independent reviewer evaluated the responses of the participants from all populations (N = 106). We thus formed two groups of scores i.e. (1) by the 4 assessors; (2) by the independent reviewer. The inter-rater reliability was calculated between the scores (ECAS Total Score, ECAS ALS-Specific, ECA ALS-Non-Specific) provided by the 4 assessors (1), and the independent reviewer (2). The inter-rater reliability analysis indicated an excellent ICC for all the scores i.e. ECAS Total Score (ICC = .88), ECAS ALS-Specific (ICC = .86), and ECA ALS-Non-Specific (ICC = .92). However, regarding the suitability of the ECAS for clinical implementation, solely the ICC of ECAS-Total Score (ICC = .88) should be considered.

<u>Table 1 – Normative Data</u>

	N	Range	Minimum	Maximum	Mean (SD)	Cut-off
Age	52	38	48	86	67.25 (9.69)	
Education	52	14	6	20	12.63 (3.22)	
Sex	26F/26M					
ALS-CBS	52	5	14	19	16.37 (1.22)	≤ 13/30
ECAS Total Score	52	36	93	129	109.73 (8.35)	≤ 93/136
ECAS-ALS Specific	52	25	68	93	80.81(6.33)	≤ 68/100
ECAS-ALS Non-Specific	52	12	24	36	28.92 (2.88)	≤ 23/36
ACE-R	52	14	85	99	91.94 (3.61)	≤ 82/100
MMSE	52	8	22	30	27.65 (1.91)	≤ 22/30
ACE-III	52	15	84	99	92.04 (3.81)	≤ 83/100
M-ACE	52	8	22	30	26.96 (2.12)	≤ 23/30

SD = Standard Deviation; Cut-offs indicate 2 SDs distance below the mean, they are presented out of the maximum score.

Table 2 – Bayesian Pearson's Correlations with Education & Age

Correlational Pairs	Pearson's r	p-value	BF_{10}
Education & ECAS Total Score	0.401 *	p<.01	11.647
Education & ECAS ALS-Specific	0.356	p<.01	4.517
Education & ECAS ALS Non-Specific	0.379	p<.01	7.213
Education & ALS-CBS	0.204	0.15	0.481
Education & ACE-III	0.284	p<.05	1.307
Education & M-ACE	0.207	0.14	0.497
Education & ACE-R	0.202	0.15	0.472
Education & MMSE	0.126	0.38	0.254
Age & ECAS Total Score	-0.163	0.25	0.331
Age & ECAS ALS-Specific	-0.213	0.13	0.528
Age & ECAS ALS Non-Specific	-0.005	0.97	0.173
Age & ALS-CBS	-0.035	0.80	0.178
Age & ACE-III	0.104	0.46	0.225
Age & M-ACE	0.077	0.59	0.199
Age & ACE-R	0.003	0.98	0.173
Age & MMSE	-0.198	0.16	0.452

BF= Bayes Factor; * $BF_{10} > 10$, ** $BF_{10} > 30$, *** $BF_{10} > 100$

Table 3 – Convergent Validity in ALS: Bayesian Pearson's Correlations

Correlational Pairs	Pearson's r	p-value	BF_{10}
ALS-CBS & ECAS Total Score	0.818 ***	p<.001	2.271e +22
ALS-CBS & ECAS ALS-Specific	0.821 ***	p<.001	8.078e +22
ALS-CBS & ECAS ALS Non-Specific	0.490 ***	p<.001	186.2
ALS-CBS & ACE-III	0.775 ***	p<.001	2.615e +9
ALS-CBS & M-ACE	0.725 ***	p<.001	3.118e +7
ALS-CBS Behavioural & ECAS Behavioural	-0.750 ***	p<.001	2356

BF= Bayes Factor; * $BF_{10} > 10$, ** $BF_{10} > 30$, *** $BF_{10} > 100$

Table 1 – Sensitivity and Specificity in differentiation between AD and ALS patients

Screen	AUC	Cut-Off	Sensitivity	Specificity
ECAS Total Score	85%	93	92%	55%
ECAS-ALS Specific	78%	68	81%	55%
ECAS-ALS Non-Specific	**99%**	**23**	**96%**	**91%**
ACE-III Total Score	91%	83	89%	76%
M-ACE Total Score	87%	23	97%	71%

The finest tool to discriminate between AD and ALS is presented in **bold**.

Screen	AUC	Cut-Off	Sensitivity	Specificity

Table 2 – Comparison Between ALS & AD Patients: Descriptive Statistics

	ALS – Mean (SD)	AD - Mean (SD)	p-value	BF_{10}
N = 50	24	26		
Sex	14M / 10F	14M / 12F		
Age	68.54 (7.05)	67.19 (4.06)	0.33	0.303
Education	11.13 (3.22)	11.12 (3.18)	0.26	0.283
ECAS Total Score	93.04 (13.27)	69.81 (17.93)	***p<.001	3396.250
ECAS-ALS Specific	65.63 (11.30)	54.19 (14.51)	*p<.001	11.616
ECAS-ALS Non-Specific	27.17 (3.45)	15.62 (5.86)	***p<.001	1.163e +8
ECAS-Behavioural	**1.42 (1.47)**	**0.38 (0.64)**	***p<.001**	**17.258**
ACE-III	85.63 (9.50)	62.31 (18.01)	***p<.001	15257.238
M-ACE	24.17 (4.80)	15.08 (6.72)	***p<.001	8387.337

SD = Standard Deviation; BF= Bayes Factor; * BF_{10} > 10, ** BF_{10} > 30, *** BF_{10} > 100

Figure 1 – Percentages of Abnormal Performance in ALS Patients

Abnormality Rates in ALS

Measure	Percentage
ECAS	50%
ALS-CBS	39%
ECAS-ALS Specific	46%
ECAS-ALS Non-Specific	21%
ECAS Language	36%
ECAS Verbal Fluency	36%
ECAS Executive Function	32%
ECAS Memory	21%
ECAS Visuospatial Abilities	11%
ECAS Social Cognition	14%
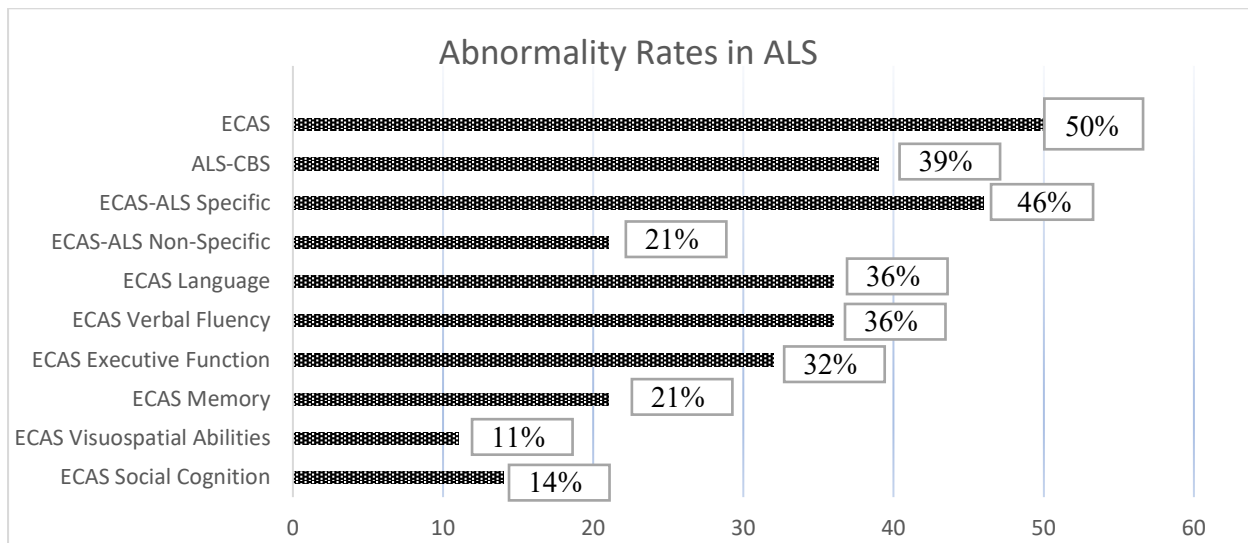
Figure 2 – Percentages of Behavioural Changes in ALS Patients

Behavioural Changes in ALS

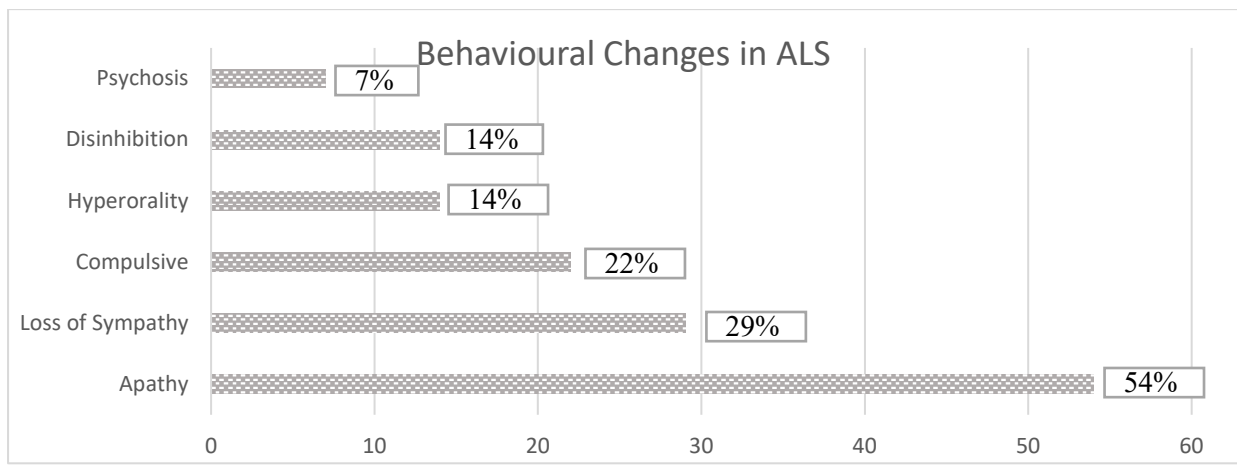| Category	Percentage
Psychosis	7%
Disinhibition	14%
Hyperorality	14%
Compulsive	22%
Loss of Sympathy	29%
Apathy	54%

Figure 3 - ROC Curves: Differentiation between AD and ALS patients